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TOPIC: THE WAVE

COURSE TITLE: REMOTE SENSING AND GIS IN LAND WATER MANAGEMENT (IT: 664)

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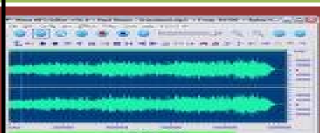

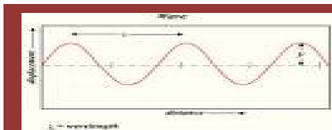

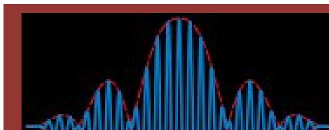

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1. INTRODUCTION

The study of waves is a very important part of introductory physics. The wave disturbances, (such as the clapping of hands, are one-time, very abrupt events, whereas others, such as the back-and-forth vibration of a guitar string, are periodic events) are present in many phenomena that surround us such as in sound and light and radio waves. The simplest wave is a single pulse that moves outward as a result of a single disturbance. However, most people are relatively unfamiliar with the properties of waves and the theoretical constructs that describe them. Because wave phenomena are so common place and people know little about them, the study of waves serves as a very good opportunity to me to develop scientific models of phenomena based upon observation and logical analysis. The waves transfer energy from one place to another with no transfer of mass. This wave is a vibratory disturbance that travels through a material or space. Wave retains very important characteristics and involved in various science.

Now a day's wave is very important in remote sensing and global positioning system for collecting remote data on surface or near to surface with the help of satellite system. Waves are non- localized, no object actually moving from one place to another but information is transported from one place to another. Waves exhibit "superposition", i.e. "no scattering". The parameters used to describe a wave are the wave speed, the wavelength and the period. The wave speed depends on the nature of the wave - sound, light, water or wave on a string - and the nature of the medium through which the wave is travelling. Many of the properties of waves that are visible in one medium such as sound or water are also visible in other wave media and make good bases for comparison. Ripple on a pond, musical sounds, laser light, exploding stars, and even electrons all display some aspect of wave behaviour.

2. DEFINATION OF WAVE

The energy of a vibration is moving away from the source in the form of a disturbance within the surrounding medium (Hall, 1980: 8). In other way, a wave is a disturbance that propagates through space and time, usually with transference of energy. While a mechanical wave exists in a medium (which on deformation is capable of producing elastic restoring forces), waves of electromagnetic radiation (and probably gravitational radiation) can travel through vacuum, that is, without a medium. Waves travel and transfer energy from one point to another, often with little or no permanent displacement of the particles of the medium (that is, with little or no associated mass transport); instead there are oscillations around almost fixed positions.

As the energy travels, the medium moves in specific ways like in ocean waves, the energy is moving through the water, but the water is not moving. Transfer of energy from water particle to water particle in circular paths or orbits transmits wave energy across the ocean known as orbital waves, and occur in the boundary between two media: air and water Because the wave moves forward, it is known as a progressive wave.

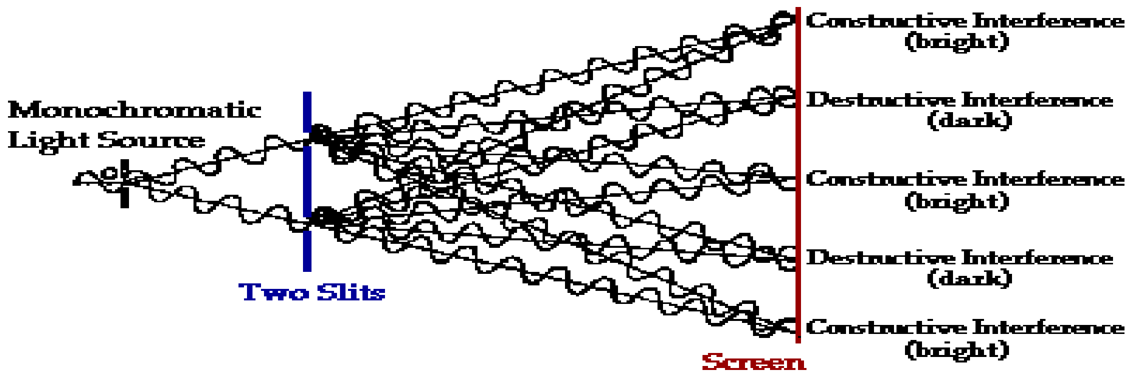
3. HOW A WAVE BEGINS

-Waves are produced by a generating force or a pulse of energy and then move away from the point of disturbance

-Restoring Force

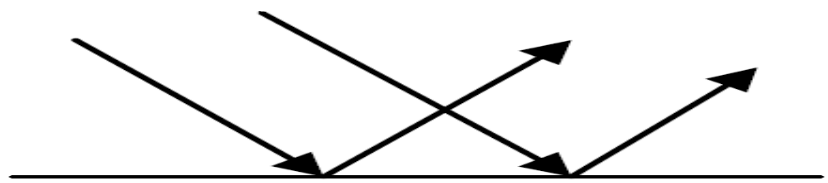
4. PROPERTIES OF WAVE

- Typically, a wave is a disturbance that propagates in a medium, which provides whatever it, is that "waves". It is best to think in terms of a medium for an intuitive grounding. But the two important kinds of waves in this course are light waves (special relativity) and probability waves (quantum mechanics), neither of which propagates in a conventional medium.
- Waves undergo interference (two waves can occupy the same place at the same time – they "interfere" and then go on. The interference can be constructive or destructive) and diffraction (bending of light around or through an obstacle (look close and this is interference as well). The engine for these phenomena is superposition.

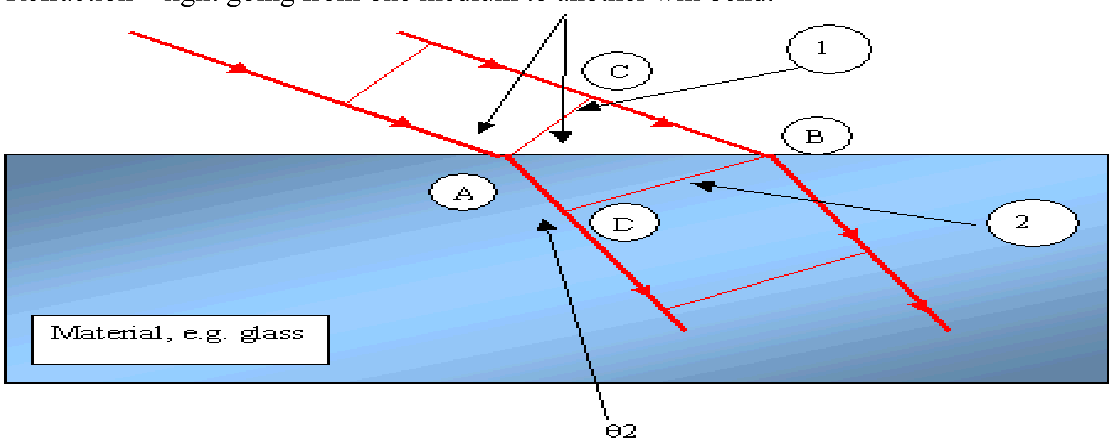


A two-point source interference pattern creates an alternating pattern of bright and dark lines when it is projected onto a screen.

- Superposition-The two wave pulses on the rope pass through each other, the resulting disturbance is a combination of the individual ones; it is a superposition of the pulses.
- Reflection – waves bouncing back from a boundary



- Refraction – light going from one medium to another will bend.



- Waves tend to be spread out in space (or in the medium).

- Polarization-The directions of the electric fields are all parallel or anti-parallel; they all lie in the same plane. Hence the wave is said to be plane polarized or linearly polarized. (Similarly, note that the magnetic field vectors all lie in a common plane, which is perpendicular to the plane of the electric field.)

  In ordinary light, which is a complex mixture of elementary waves, the only restriction on the plane of vibration of the electric field is that it should be at right angles to the direction of travel of the light wave. Otherwise it can have any orientation. Consider radiation from an ordinary light globe. The total electric field at a particular place (due to the radiation from all parts of the filament) changes direction quite randomly but always stays perpendicular to the direction of travel of the light wave. Light waves which behave like this are said to be randomly polarised or unpolarised (figure 1.6).

  However, if by some means the electric field is restricted to one plane only, i.e. if the individual elementary waves all have the same polarisation, then the light beam as a whole is said to be plane polarised or linearly polarised.

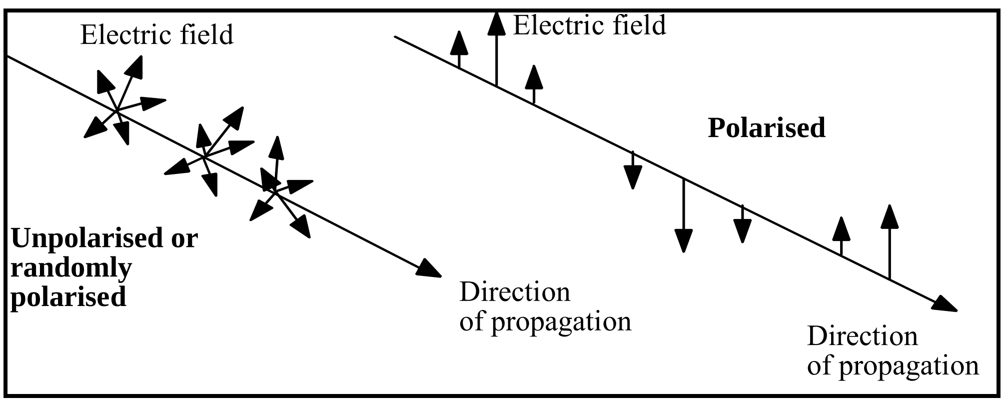


Figure 1.6. Polarised and unpolarised light

- The energy/intensity carried by waves is proportional to the square of whatever waves (at least for linear waves).
- Waves obey a wave equation. Although a somewhat non-intuitive mathematical abstraction (a partial differential equation), it really packages many properties of waves in a very convenient form; and many kinds of linear waves obey the same wave equation, called "the" wave equation—so if you learn about one of those kinds you know about them all.

5. VARIOUS TYPES OF WAVE

1) **Longitudinal wave** – Vibration of the medium moves parallel to the direction in which the wave travels. It can move through most materials because the materials can be compressed and restoring forces.
   Example- sound - Guitar String.

2) **Transverse wave** – Vibrational disturbance (Vibration of the medium) which is perpendicular to the direction in which the wave travels. It can move only through a

material that has some rigidity; transverse waves cannot exist within a fluid because the molecules simply slip by each other.
Example-waves on a rope, water waves, seismic waves, electromagnetic waves (light, microwaves, radio waves)

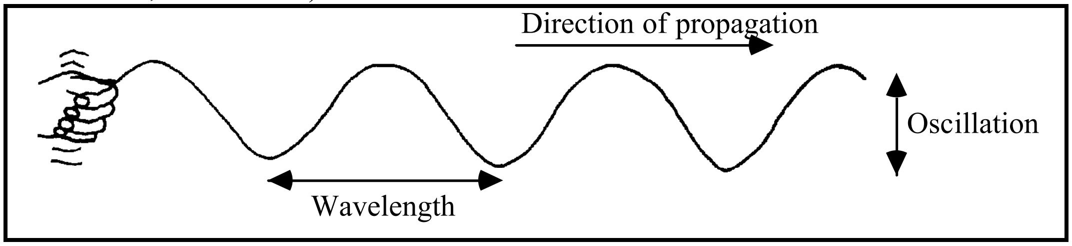


Figure 1.1. A transverse wave on a string

Note: Both types of wave can exist in the chain of balls. If the ball is moved vertically, a transverse wave is generated. If the ball is moved horizontally, the wave is longitudinal.

3) **Mechanical wave-** Mechanical waves which travel in a material medium, such as sound waves, water waves and earthquakes, the energy is mechanical energy - kinetic energy plus potential energy. The potential energy is associated with the forces between particles and their displacements from their equilibrium positions, while the kinetic energy is associated with their movement. The wave energy is propagated through the continual interchange between potential and kinetic energy as the medium oscillates.

4) **Electromagnetic wave-** Electromagnetic waves can travel through empty space so there is no material medium involved - the energy oscillates between the electric and magnetic fields. Whatever the kind of wave, there are always at least two physical variables associated with its propagation. In the case of sound waves these variables might be the velocity and displacement of particles and in the case of light they are the electric and magnetic fields.

5) **Standing wave-** When a periodic wave is confined, new effects emerge sue to the superposition of the reflected waves with the original ones. Let's return to the example of a periodic wave moving down a ripe toward a rigid post. When the periodic wave reflected form the post, it superimposes with the wave heading toward the post. The complete pattern results from the superposition of the original wave and reflections form both ends. In general, we get a complicated pattern with small amplitude, but certain frequencies cause the rope to vibrate with large amplitude. Although the superimposing waves move along the rope, they produce a resonant pattern that does not move along the rope. Because the pattern appears to stand still (in the horizontal direction), it is known as a standing wave. Waves that do not propagate from one location to another and do not have a velocity and appears as alternating crests and troughs at some location separated by nodes and anti-node.

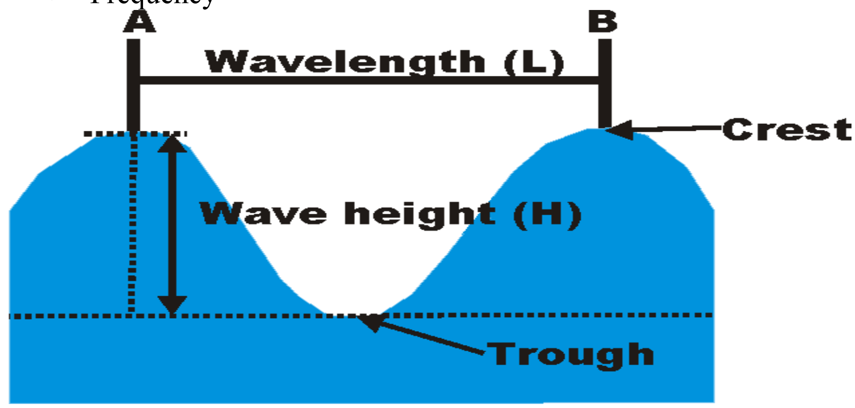
6) **Periodic wave-**A rope moved up and down with a steady frequency and amplitude generates a train of wave pulses. All the pulses have the same size and shape as they travel down the rope. For one thing, unlike the single pulse, periodis waves have a

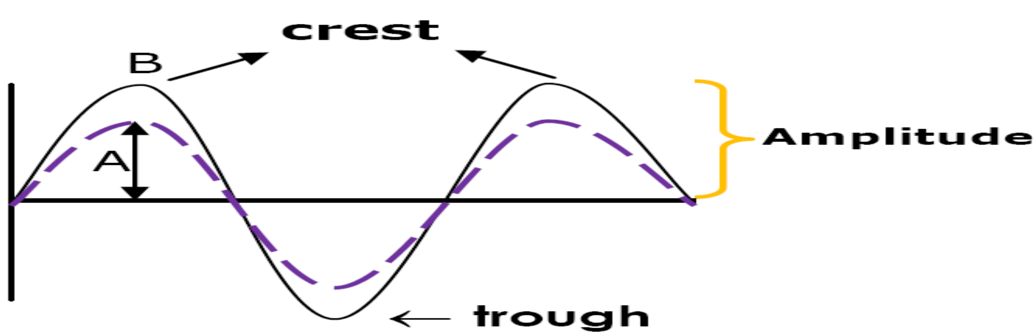
frequency. The frequency of the wave is the oscillation frequency of any piece of the medium.

An important property of a periodic wave is the distance between identical positions on adjacent wave pulses, called the wavelength of the periodic wave. This is the smallest distance for which the wave pattern repeats. It might be measured between two adjacent crests, or two adjacent troughs, or any two identical spots on adjacent pulses.

Periodic waves are characterized by

- *crests* (highs)
- *troughs* (lows)
- Wave length(L)
- Amplitude(A)
- Time Period(T)
- Frequency





6. CLASSIFICATION OF WAVE

Waves are classified by-

a) Wind waves are caused by wind
b) Seiche -Storm surge, seismic wave in an enclosed by or a sudden change in atmospheric pressure cause the resonant rocking water known as a seiche.

c) Tsunami- Landslides, earthquakes and volcanoes can cause tsunami, or seismic wave.
d) Tides Gravitational pull of the moon and sun cause tides, a type of wave
e) Free waves are formed and then propagate on their own
   Ex: Wind waves, tsunami, seiche
f) Forced waves are maintained by the disturbing force
   Ex: tides
g) Capillary waves that ripple across a puddle
h) Wavelength-
   i. Capillary waves: <1.73 cm
   ii. Wind Waves: 60 – 150 m
   iii. Seiche: Highly variable
   iii. Tsunami: 200 km
   iv. Tide: ½ Earth's Circumference
i) Deep Water, Transitional water waves, Shallow Water Waves
j) Breaking Waves
k) Internal Waves are subsurface waves that can form between layers of different densities
l) Nonrecurrent wave -include tidal bores, tidal waves, explosions, and light pulses emitted by supernovas (exploding stars).

7. SOUND WAVE

Sound is a longitudinal wave. The molecular disturbance in the air is parallel to the forward motion of the wave. This wave of pressurized (air molecules compressed up against one another) air oscillates about an average value. This average value is the average atmospheric pressure in the environment in which the sound waves are being transmitted. The frequency of a sound wave is the number of "pressure" oscillations produced each second. Sound moves through air as the molecules move colliding with the molecules next to them, which in turn move outwards colliding with the next set of molecules, etc.. The speed of sound is a function of the density of the medium. In air this means that the temperature and pressure of the air affect the speed of the wave. This speed is equal to 343 m/s at one atmosphere of pressure and room temperature.

Sound travels through solids and liquids at a faster rate than in gases. Sound will not travel through a vacuum, because sound requires a medium to travel through. In movies a sound should not be heard when something explodes at a distance in the vacuum of space. On the other hand light should be shown, if any is given off by the explosion, because light does travel in a vacuum.

Sound can and does reflect off of objects. An echo is the result of a sound wave bouncing off of a barrier and returning towards the source of the sound. Sound waves experience diffraction. They can pass through small openings and spread out into the space beyond the opening. Sound is also observed to bend around corners, which also an example of diffraction. Sound waves can and often do experience interference. You have probably heard two different sources of sound at the same time and the interference of the sound waves prevented you from hearing either of the sources very clearly. Destructive interference can create problems in theatres, because of the cancelling of the waves that occurs at the nodes where the sound waves cancel one another. Sound waves can also experience constructive interference. In this case two sounds will be louder than either sound heard separately. Sound

waves do have wavelengths. The wavelength of a sound wave is the distance between consecutive areas of maximum pressure. These regions of maximum pressure would be called the crests of the sound waves, while the troughs would be the regions of low pressure between the regions of high pressure. The human ear is not capable of hearing all sounds. The typical human ear can hear sounds over a range of 20 Hz to 20 kHz.

8. LIGHT WAVE

Christiaan Huygens (1629-1695) proposed that light was composed of waves. He was the first person to explain how wave theory can work with the laws of geometric optics. He stated that light waves propagate in straight lines at the speed of light. Travelling in straight lines as plane wave fronts would allow reflection to occur similar to the geometric optics, because the angle of incidence = angle of reflection (see picture 1). Huygens' theory of refraction with light waves involves the light waves moving slower in a denser medium.

In the wave model light is viewed as electromagnetic waves. Since these waves consist of oscillating electric and magnetic fields which can exist in empty space, light can travel through a vacuum. Since light can be analysed as a complex mixture of a huge number of individual electromagnetic waves, the important properties of light and other electromagnetic waves can therefore be understood in terms of the properties of these simple elementary waves.

At any point on the path of a simple harmonic light wave the strengths of the electric and magnetic fields are continually changing. At each point the two fields always change in step, so that the maximum value of the electric field occurs at the same time as the maximum magnetic field. The electric and magnetic fields point in directions at right angles to each other and also at right angles to the direction in which the wave travels. Since a complete knowledge of the electric field determines the magnetic field, the wave can be described adequately by specifying the electric field only.

Figure 1.5 is an instantaneous representation of the fields in part of an elementary electromagnetic wave. Here it is clear that the electric and magnetic fields are in phase, their maxima occur at the same place at the same time. Since both fields are perpendicular to the direction of travel of the wave, the wave is said to be **transverse**. (A wave in which the direction of the wave property is parallel to the direction of travel is called a longitudinal wave.)

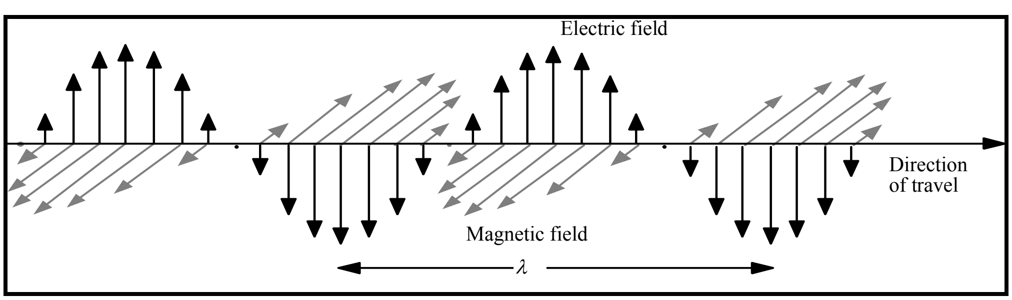


Figure 1.5. Instantaneous plot of part of a simple electromagnetic wave
The direction of each field is shown by the direction of the arrow and its magnitude is represented by the length of the arrow.

9. THE ELECTROMAGNETIC SPECTRUM

The spectrum of electromagnetic waves is divided up into a number of arbitrarily named sections. The dividing lines between these sections are determined by the detailed properties of a particular range of wavelengths. But there is considerable overlap and the divisions are to some extent arbitrary.

When any elementary electromagnetic wave, including light, passes from one medium into another, its frequency remains the same. This can be explained in terms of the interaction between the radiation and the electrons in the material. The electromagnetic waves actually interact with the atoms or unbound electrons which then re-radiate the energy, forming a new wave at the same frequency.

The simplest kind of wave to describe mathematically is a simple harmonic wave that travels in one direction. The wave property (electric field, pressure or whatever it is that does the waving) is represented here by *W* and varies with position *x* in space and with time *t*. The wave can be described by the equation:

$$W = A \sin(kx - \omega t + \phi) \qquad \text{... (1.1)}$$

in which A, k, ϕ and ω are constants. Their significance is discussed below.

This equation tells us several things about the wave. The expression in parentheses, $(kx - \omega t + \phi)$), which is called the phase of the wave, tells what stage the oscillation has reached at any point x and time t. The quantity ϕ is called the initial phase. We can get a kind of snapshot of the wave by making graphs of W plotted against x for particular values of the time t (figure 1.3). The graphs show the familiar sine-curve shape of the wave. The constant A is called the amplitude of the wave and the value of the wave property varies between $-A$ and $+A$. As time progresses the wave moves forward, but its shape is the same.

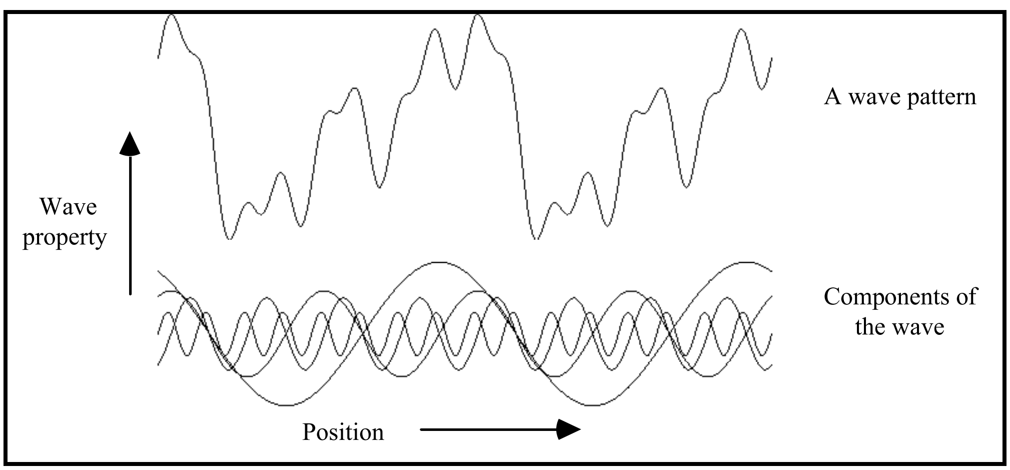


Figure 1.2. Analysis of a wave in terms of elementary sine waves The complex wave is plotted in the top diagram and the mixture of its four components is shown below.

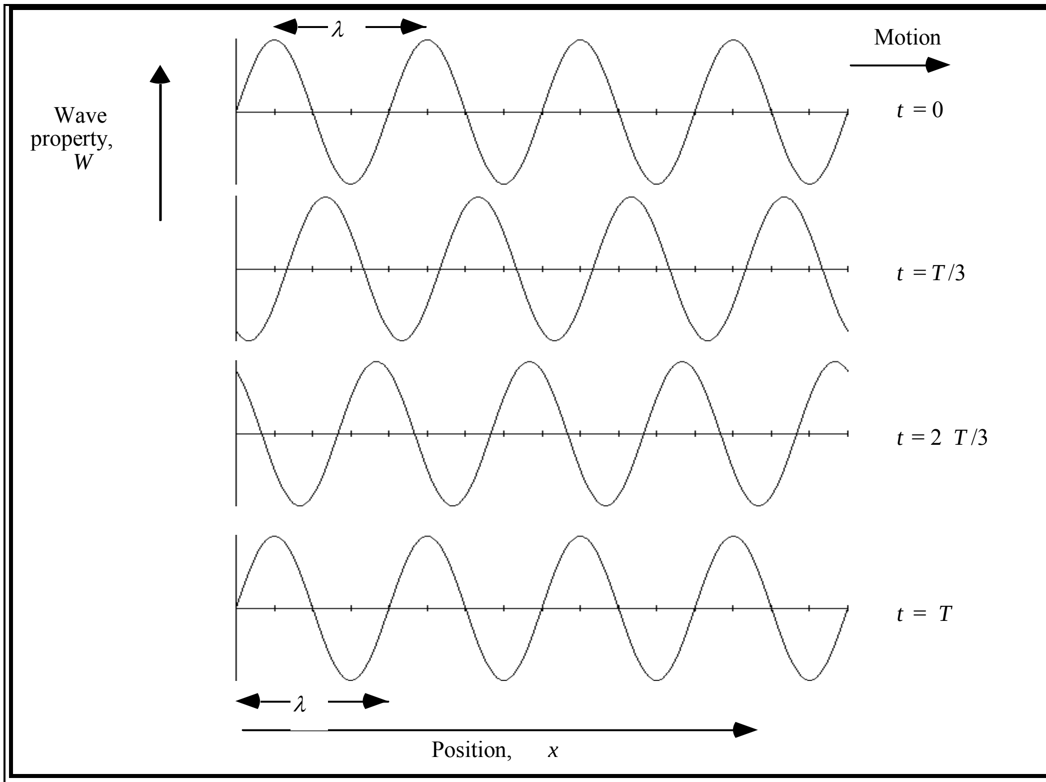


Figure 1.3. Progress of a simple wave
The whole wave pattern moves to the right. In one period (*T*) it moves one wavelength (λ).

The equation (1.1) and the graphs (figure 1.3) both show that the pattern of the wave is repeated exactly once every time that the position coordinate *x* increases by a certain amount λ which is called the wavelength. The constant *k* in equation (1.1) is called the propagation constant or the wave number. It is inversely related to the wavelength:

$$\lambda = \frac{2\pi}{k}.$$

By looking at what happens at a fixed point (*x*) as the wave goes past, we can see that the variation of the wave property with time is also described by a sine function: the variation of *W* is a simple harmonic oscillation (figure 1.4).

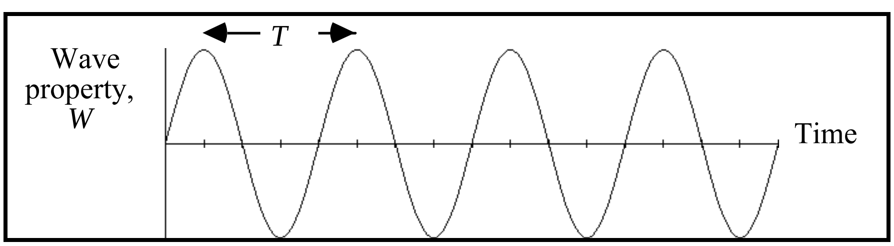


Figure 1.4. The wave oscillation at a fixed location
Although *W* is now plotted against time, the shape of the graph is just like the shape of the wave shown in figure 1.3 .

The constant ω in the equation is the angular frequency of the oscillation and the wave. The wave's period *T* and its frequency *f* are given by the relations:

$$T = \frac{2\pi}{w} = \frac{1}{f} . \qquad \text{... (1.2)}$$

By studying the graphs in figure 1.3 you should be able to satisfy yourself that the wave moves forward by one wavelength in one period, so the wave speed must be equal to λ / T or $f\lambda$:

$$v = f\lambda . \qquad \text{... (1.3)}$$

Note that the wave equation quoted above describes the progression of an idealised wave in a one-dimensional space. The main differences for real waves in three-dimensional space are that the amplitude A generally decreases as the wave moves further away from its source and that we need some way of describing how the waves spread out as they go.

9.1 RADIO WAVE

Radio waves have wavelengths from about 1 m upwards. They are produced by connecting an electronic oscillator to an antenna. The oscillating electrons in the antenna then lose energy in the form of electromagnetic waves. Radio waves are used for radio and television broadcasting and long-distance communications.

9.2 MICROWAVE

Microwaves are short radio waves with wavelengths down to about 1 mm. They can be produced electronically by methods analogous to the production of sound waves when you blow across the top of a resonating cavity such as a bottle. Because microwaves are not absorbed very strongly by the atmosphere, but are reflected well off solid objects such as buildings and aircraft, they can be used for radar location of distant objects. Microwaves are also used extensively for communications but they require direct line-of-sight paths from transmitter to receiver so that microwave stations are located on top of hills and tall structures.

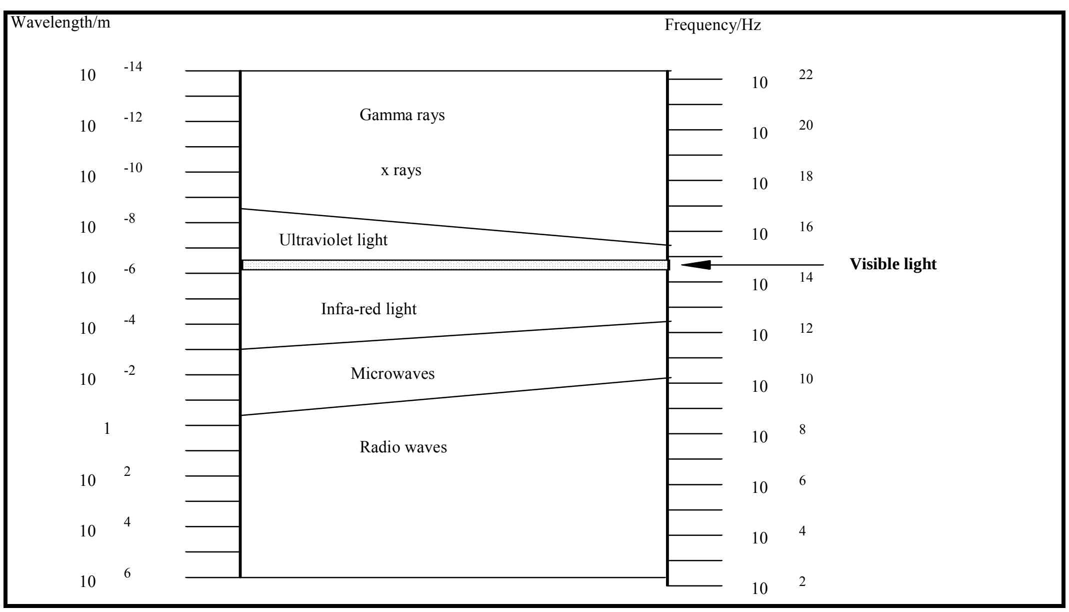


Figure 1.12. The spectrum of electromagnetic waves Note the logarithmic scales.

9.3 INFRARED RADIATION

The infrared part of the spectrum comprises wavelengths from 0.1 mm (far-infrared) down to about 700 nm. Infrared radiation is emitted by excited molecules and hot solids. Much of the energy released by the element of an electric oven is in the form of infrared radiation. The radiation is very easily absorbed by most materials so the energy becomes internal energy of the absorbing body. When you warm your hands by a fire you are absorbing infrared radiation.

9.4 VISIBLE LIGHT

Light is that part of the electromagnetic spectrum which we can see. Visible light is emitted by excited atoms and molecules and by very hot solids.

9.5 ULTRAVIOLET RADIATION

Ultraviolet 'light' has wavelengths less than 400 nm. It is emitted by excited atoms. The 'black light' used to produce fluorescence in light shows is ultraviolet. Much of the ultraviolet radiation from the sun is absorbed by the atmosphere but that which gets through can cause sunburn and skin cancers. Ultraviolet light can also be harmful to the eyes. The irradiance of ultraviolet light increases at high altitudes where the atmosphere is thinner. Part of the concern about the depletion of the atmosphere's ozone layer is based on the fact that the ozone layer absorbs ultraviolet radiation from the sun.

9.6 X RAYS AND GAMMA RAYS

The wavelengths of x rays and gamma rays overlap, but the different names indicate different ways of producing the radiation. X rays are produced in processes involving atoms and electrons. For example they can be produced by bombarding a metal target with high energy electrons. They are also emitted in some high-energy atomic energy level transitions. X rays usually have wavelengths less than 10 nm. On the other hand the term gamma rays is reserved for electromagnetic radiation emitted in sub-atomic processes such as the decay of excited nuclei or collisions between sub-nuclear particles. Gamma radiation generally has wavelengths less than 0.1 nm. It is emitted by excited nuclei of atoms.

10. REFERENCES

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